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A planning tool for integrating crop choices with weed management in the Northern Great Plains

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Abstract

Crop production in the Northern Great Plains is rapidly changing because of no-till practices; producers now grow a diversity of crops with winter wheat to increase production as well as to manage weeds. With the multitude of crops available, producers are asking for guidelines to sequence crops in rotations that help weed management. We developed a planning tool that lists various choices with crops when designing a rotation; the choices are arranged by impact on weed dynamics as quantified by research in the region. The tool includes choices among crops, such as varying crops with different life cycles, planting dates, or row spacing, and choices within an individual crop, such as varying cultivar or planting date. Choices among crops impact weeds the most, whereas choices within an individual crop are less effective and usually lead to lower crop yield. For example, rotations comprised of two cool-season crops followed by two warm-season crops can reduce weed populations six- to 12-fold. In contrast, replacing a standard-height cultivar with a taller cultivar that is more competitive with weeds, is often inconsistent for weed management, whereas crop yield may be less. Producers associated with the Northern Plains Sustainable Agricultural Society felt that the planning tool would encourage long-range planning as well as help integrate weed management with the design of cropping systems. The purpose of the tool is to encourage ecologically based weed management, which can reduce herbicide inputs by 50% for Northern Great Plains producers.

Key words: cultural practices, ecologically based weed management, rotation design

Introduction

In the semi-arid Northern Great Plains, an area that ranges from western North Dakota to northeastern Colorado and western Kansas, winter wheat–fallow has historically been the prevalent crop rotation. During fallow, neither crops nor weeds are allowed to grow, as the goal of fallow is to store precipitation in soil. Soil water gained during fallow improves growth of the following winter wheat, subsequently reducing yield variability and crop loss due to erratic precipitation.

In recent years, however, producers have changed this rotation to include more crop diversity. One reason for this change is development of no-till systems that maintain crop residue on the soil surface. No-till improves water relations[1] and soil health[2], such that producers can grow several crops in a row before fallowing. Producers are now growing corn (*Zea mays* L.), proso millet (*Panicum miliaceum* L.), sorghum [*Sorghum bicolor* (L.) Moench], sunflower (*Helianthus annuus* L.), canola (*Brassica rapa* L.), and dry pea (*Pisum sativum* L.) in sequence with winter wheat and fallow[3,4].

Crop diversity in no-till systems offers producers a multitude of benefits, such as improved productivity and economics. With appropriate sequencing, crop yield can be increased due to the rotation effect[5], whereas land productivity can be almost doubled with diverse rotations, compared with winter wheat–fallow[3]. Improved productivity increases net returns by 25–40%[6].

No-till systems are successful because herbicides replaced tillage for controlling weeds. Yet, producers are concerned with herbicide use because resistant biotypes of several weed species are now common in this region[7]. For example, atrazine controls weeds in both corn and fallow. But now, kochia [*Kochia scoparia* (L.) Schrad.], green foxtail [*Setaria viridis* (L.) Beauv.] and barnyardgrass

[*Echinochloa crus-galli* (L.) Beauv.] are resistant to atrazine. Because of resistant weed species, production costs have increased considerably as producers are forced to use more expensive management tactics[8].

With the diversity of crops available in this region, producers can minimize herbicide resistance and input costs with ecologically based weed management. The ecological approach emphasizes weed population management and cultural practices that enhance crop competitiveness with weeds[9]. A key strategy for reducing weed populations is to rotate crops with different life cycles[10]; lower weed density enhances effectiveness of cultural practices in controlling weeds, such that, in some crops, herbicides are not needed for weed management[11]. Growing crops without herbicides reduces selection pressure for resistance as well as input costs. An additional benefit of crop diversity is that producers have more opportunities to rotate herbicides with different modes of action, further reducing selection pressure for herbicide resistance[12]. Based on income tax records for farm expenses, the ecological approach has enabled producers in the Northern Great Plains to reduce herbicide inputs by 50%[10].

When designing a rotation, producers consider a multitude of factors, such as choice of crops, crop sequencing and available markets, as well as strategies for soil, nutrient, time and equipment management. If rotations are comprised of only one or two crops, planning for weed management usually emphasizes choice and rate of herbicide used. With the ecological approach, however, practices that affect weed populations and crop competitiveness are included in the design of rotations.

Extensive information is available related to alternative cropping systems, crop sequencing and weed management. Yet, seldom are producers provided with a framework to organize the massive database within a specific discipline, much less at the cropping systems level. Because producers are exploring new rotations, they are asking for a guide to integrate crop choices with weed management. Our goal was to develop a planning tool that encourages the merging of ecological principles related to weed management with other factors involved in designing rotations. Our ultimate goal is to help producers manage weeds, reduce herbicide inputs and minimize development of herbicide-resistant weeds.

Planning Tool: Guidelines for Crop Choices that Help Weed Management

Our planning tool (Fig. 1) lists possible choices with crops that can be integrated into a rotation. The choices are arranged by impact on weed dynamics, with the choice of greatest impact being listed at the top; the figure visually ranks the choices in a step-like design to help the producer compare his current strategy with other possible choices. In the following text, we describe the response of weed dynamics to each choice, based on research conducted in the Northern Great Plains.

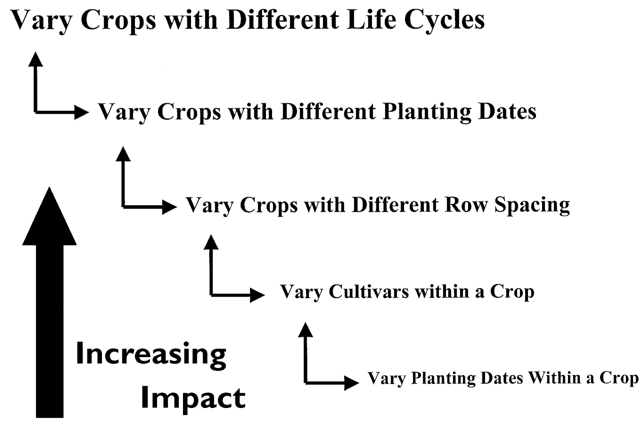

Figure 1. Planning tool to guide crop choices in relation to weed management, based on weed ecology research conducted in the Great Plains.

Vary crops with different life cycles

Weed species tend to associate with crops of similar life cycles[13], thus rotating crops with different life cycles disrupts population growth of weeds[14]. In the Northern Great Plains, where both winter and summer annual crops are well adapted, producers can sequence crops to accentuate life cycle differences. The impact of this strategy on weed dynamics can be striking, as shown in a long-term rotation study at Akron, Colorado[10]. In this study, a series of rotations was established with conventional practices used by producers in the area. After 8 years, weed biomass differed sixfold between monocultures and rotations comprised of crops with different life cycles.

A surprising finding, however, was that weed biomass was affected by crop sequence only if there was a 2-year interval between crops with similar life cycles. For example, a winter wheat–corn–proso millet rotation eliminated winter annual weeds such as downy brome (*Bromus tectorum* L.), but densities of summer annual grasses, such as green foxtail and witchgrass (*Panicum capillare* L.), increased across time. But, if rotations were comprised of two winter annual crops followed by two summer annual crops, densities of both winter and summer annual weeds were minimal.

A similar trend occurred with crop sequencing at another rotation study in central South Dakota[10]. After 10 years, a winter wheat–fallow rotation was infested with downy brome at 31 plants m^{-2} (Fig. 2). When chickpea (*Cicer arietinum* L.), a summer annual crop, was added to the rotation (W-CP in Fig. 2), weed density increased to 60 plants m^{-2}; the weed community included summer annual grasses such as green foxtail and witchgrass, as well as downy brome. A three-crop rotation comprised of one winter annual and two summer annual crops, winter wheat–corn–chickpea, eliminated downy brome but green foxtail

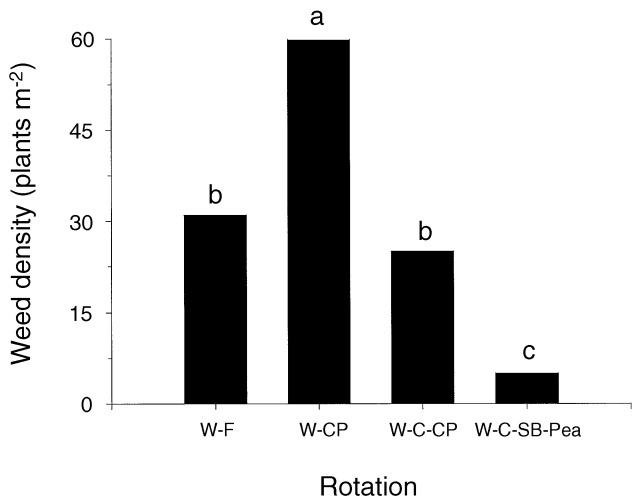

Figure 2. Weed density in four rotations of a cropping systems study at Pierre, South Dakota (W, winter wheat; F, fallow; CP, chickpea; C, corn; SB, soybean; and Pea, dry pea). The study was initiated in 1990 and data recorded in 2001 and 2002. Weeds were controlled with conventional practices during the study. Treatment means represent weed density averaged across all crops within each rotation; bars with the same letter are not significantly different based on Fisher's LSD ($P < 0.05$). (Adapted from Anderson[10].)

Figure 3. Longevity of green foxtail and downy brome seeds in the seed bank, when seed remains within the top 3 cm of soil. (Adapted from Anderson[10].)

and witchgrass density averaged 25 plants m^{-2}. However, a rotation comprised of two cool-season crops, winter wheat and dry pea, followed by two warm-season crops, corn and soybean (*Glycine max* Merrill), minimized weeds, such that weed density was 12-fold less compared with winter wheat–chickpea. As found in the Akron, Colorado study, lowest weed density occurs in four-crop rotations that balance cool- and warm-season crops in 2-year intervals.

The effect of the 2-year interval is related to the natural decline of weed seed density in soil. The number of live weed seeds in soil declines rapidly if new seeds are not added[15]. Both downy brome and green foxtail seed densities decrease to less than 5% after 2 years in soil (Fig. 3). Weed seed production can be eliminated during years of crops with different life cycles; thus a 2-year interval reduces potential seedling density in future crops by more than 95%.

In the drier areas of the Northern Great Plains, where fallow is still prominent, producers can accrue this 2-year life cycle interval with rotations such as winter wheat–corn–fallow or winter wheat–proso millet–fallow. The fallow period fits either life cycle category if weeds are controlled during fallow, thus winter wheat and fallow comprise a 2-year interval to minimize summer annual weed populations, whereas the 2-year interval of corn or proso millet plus fallow reduces density of winter annual weeds in soil.

For producers in the more humid areas of the Northern Great Plains, this life cycle benefit on weed management can be further enhanced by including perennial forages in rotation with annual crops[16]. Mowing for forage harvest prevents seed production of most weeds, thus favoring decline of weed seed densities in soil during the forage interval. Lafond et al.[17] suggested perennial forage intervals of 3–5 years for maximum benefit with suppressing weeds, maintaining forage stands and improving yields of following crops.

But some species, such as green foxtail, are able to produce seeds in conventional harvesting schedules with perennial forages[18]. With these species, perennial forages may not reduce seed density in soil. Another trend with weed dynamics in perennial forages is that winter annual weeds, such as dandelion [*Taraxacum officinale* (Weber in Wiggins)], field pennycress (*Thlaspi arvense* L.) or downy brome, may proliferate because of their earlier growth than most forages, which allows plants to establish and produce seeds.

Vary crops with different planting dates

Producers can also help weed management by rotating crops with similar life cycles but different planting dates[19]. For example, the weed community in northeastern Colorado displays two peak periods of emergence (Fig. 4); the first peak represents cool-season weeds, such as kochia [*Kochia scoparia* (L.) Schrad.] and Russian thistle (*Salsola iberica* Sennen & Pau), whereas warm-season weeds, such as green foxtail, witchgrass and pigweed species (*Amaranthus* spp.), emerge during the second peak, in late May and early June[20]. Corn in this region is usually planted in early May, whereas sunflower or proso millet are planted in early June. Later planting of sunflower or proso millet in the year after corn allows producers to control summer annual weed seedlings that emerge between May 1 and early June, which is 63% of the seasonal emergence between May 1 and August 1 (Fig. 4).

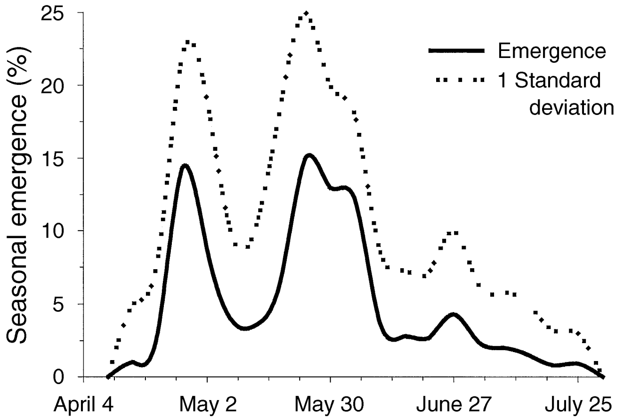

Figure 4. Weed community emergence pattern for a semi-arid site at Akron, Colorado. The weed community consisted of 16 plant species; data were collected from two tillage treatments—no-till and tillage with a sweep plow—and averaged across 7 years. The dotted line represents one standard deviation. (Adapted from Anderson[20].)

However, reversing this sequence, by planting either proso millet or sunflower before corn, is not effective because of extensive volunteer crop plants infesting corn. Our rotation study at Akron, Colorado included a winter wheat–proso millet–corn–fallow rotation; we terminated that rotation after 6 years because of difficulties in controlling volunteer proso millet in corn. The emergence period of volunteer proso millet ranges from early May through June, leading to volunteer densities that required higher herbicide inputs to avoid yield loss in corn.

The contrast in planting dates of winter wheat and dry pea also favors weed management, provided that dry pea precedes winter wheat in the rotation. Winter annual weeds such as downy brome, jointed goatgrass (*Aegilops cylindrica* Host), and blue mustard [*Chorispora tenella* (Pallas) DC] emerge mainly between September and March. Dry pea is planted in late March or early April, thus winter annual weeds can be controlled easily before planting. If seedlings of these weeds emerge after dry pea planting, seed production is drastically reduced because of less plant growth and inconsistent vernalization. The early growth and canopy development of winter wheat minimizes the impact of dry pea volunteers that emerge in April or May. However, if dry pea follows winter wheat, volunteer wheat seedlings will require additional control tactics in dry pea. With the proper sequence, rotating crops with different planting dates within the 2-year life cycle interval can enhance the impact of rotation design on weed dynamics.

Vary crops with different row spacing

An ecological principle related to plant competition is that the first plant to capture resources gains a competitive edge[21]. One strategy that favors resource capture is to plant crops in narrow rows, as demonstrated in a study that compared weed growth in corn, sunflower and proso millet[22]. Corn was planted during the first week of May and in rows spaced 76 cm apart. Sunflower and proso millet were planted in early June; row spacing was 76 cm for sunflower and 20 cm for proso millet. Weeds, primarily green foxtail and witchgrass, were allowed to grow for 7 weeks in each crop, then harvested for biomass. Weed biomass in sunflower was only 35% that of corn (Fig. 5), reflecting the difference in weed density due to later planting of sunflower. Narrow rows with proso millet reduced weed biomass almost threefold compared with sunflower. Combining two management choices, such as selecting a crop grown in narrow rows and planting the crop later, impacted weeds tenfold, as shown with proso millet and corn.

In the Northern Great Plains, crops planted in wide rows, such as corn and sunflower, are not competitive with weeds[10], but equipment technology is evolving such that these crops now can be planted in narrower rows; this practice, when combined with other cultural practices, improves their tolerance of weeds. At Akron Colorado, corn grown at 47,000 plants ha^{-1} in narrow rows (50 cm), with N fertilizer banded by the seed, reduced weed biomass by 60% compared to the conventional system of 38,000 plants ha^{-1} planted in 76 cm row spacing and with N broadcast[23]. Because of reduced weed growth, corn yield loss due to weeds was reduced fourfold with the narrow row production system.

Vary cultivar within a crop

Cultivars differ in their competitiveness with weeds. Challaiah et al.[24] found that downy brome biomass production varied by 35% among winter wheat cultivars; cultivar traits associated with competitiveness were high tiller density and plant height. Winter wheat yield loss due to downy brome interference also varied twofold, with less yield loss in taller cultivars. Similar trends were found with proso millet competition with redroot pigweed (*Amaranthus retroflexus* L.); taller cultivars reduced weed growth and tolerated weed interference with less yield loss[11].

This strategy has some limitations. First, taller cultivars usually yield less because resources are invested in extra plant stem biomass[26]. Secondly, cultivar impact on weeds is not consistent over years, varying with environmental conditions and time of weed emergence[27]. Also, in years where weed density is low, producers may sacrifice crop yield with taller cultivars when weed suppression is not needed.

However, impact of cultivar choice on weed management can be improved by integrating this tactic with other cultural practices to strengthen the crop's canopy. For example, the competitiveness of winter wheat with jointed goatgrass was increased sixfold by combining a tall cultivar with higher seeding rates and nitrogen placement[25]. Seed production of jointed goatgrass and

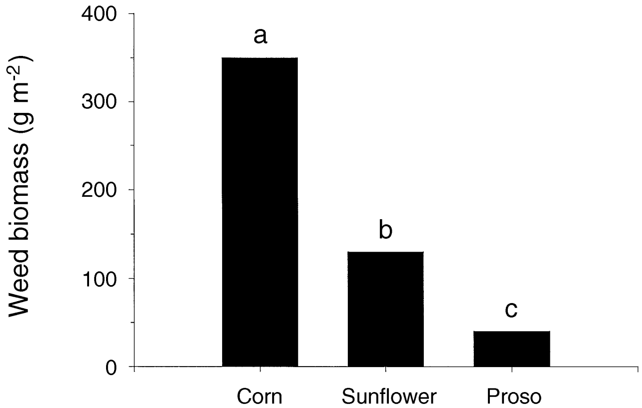

Figure 5. Weed biomass in corn, sunflower and proso millet. Biomass was determined 7 weeks after crop emergence; data were averaged across 3 years. Treatment bars with the same letter are not significantly different based on Fisher's LSD ($P < 0.05$). (Adapted from Anderson[22].)

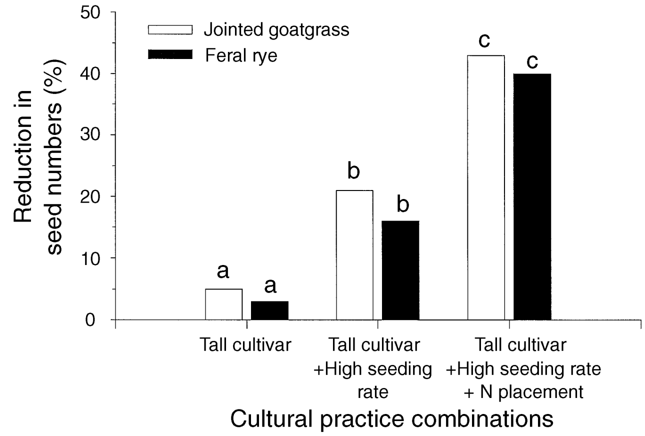

Figure 6. Seed production of jointed goatgrass and feral rye as affected by cultural practices in winter wheat, Akron, Colorado. Treatment means were compared to the conventional system of winter wheat production: semi-dwarf variety, normal seeding rate, and N applied broadcast. Data averaged across 3 years; bars with the same letter are not significantly different based on Fisher's LSD ($P < 0.05$). Means for the tall cultivar did not differ from those of the conventional system. (Adapted from Anderson[25].)

feral rye (*Cereale secale* L.) was reduced by 40–45% with this cultural approach compared to conventional practices with winter wheat (Fig. 6). Similar results occur with proso millet; adding other cultural practices to tall cultivars improves proso millet competitiveness with pigweed species several-fold[23]. Furthermore, with both species, the cultural approach improves competitiveness of short cultivars such that weeds can be suppressed without sacrificing crop yield, as occurs with the taller cultivars.

Vary planting dates within a crop

A common strategy used by producers for weed management is to delay planting of the crop. This strategy allows more time for weed seedlings to emerge and be controlled before planting. However, this tactic is not consistently effective, especially in semi-arid regions with erratic rainfall. In Colorado, delayed planting of winter wheat was effective in controlling downy brome in only one year out of six[28]. Yet, winter wheat yield was reduced every year due to late planting. The later planting of winter wheat reduces yield because the crop is more vulnerable to plant diseases and environmental stresses[29]. Similar yield loss with delayed planting also occurs with proso millet[30], corn[31] and sunflower[10].

Effectiveness of delayed planting with a crop contrasts with the impact of varying crops with different planting dates. Rotating crops with different planting dates avoids the detrimental impact on yield with delayed planting of a crop, yet still reduces weed density. Delay of planting within a crop may be effective if rain occurs right before planting; by waiting, producers can eliminate the first flush of weeds that emerge. Otherwise, weed management will benefit more from choices involving different crops.

Impact of Crop Management Choices on Weed Dynamics

Producers can enhance weed management by crop management choices; note the six- to 12-fold impact of rotating cool- and warm-season crops in a 4-year cycle. Also, diversifying crops within a life cycle interval, such as summer annual crops, can lead to a three- to fourfold impact on weed dynamics. Sequencing crops with different planting dates and row spacing, such as corn and proso millet, can reduce weed biomass tenfold. The options available for an individual crop, such as varying cultivar or planting dates, have a minor impact on weed management; in most cases, results may be ineffective whereas crop yield may be sacrificed.

Producer Response to the Planning Tool

We presented this planning tool to members of the Northern Plains Sustainable Agriculture Society during their national meeting in 2002. This Society is comprised mainly of organic producers who rely on cultural practices to manage weeds. The producers felt that the tool would be useful in planning cropping systems, especially with the arrangement of strategies based on impact. An intriguing observation was that most producers in the Society were using choices within an individual crop, either changing cultivar or planting date, for weed management. During our discussion, they recognized that their current weed management approach was reactive, responding to weed problems as they developed rather than planning rotations to manage weed populations. The producers encouraged us to pursue development of this tool to encourage thinking on ecological principles and long-range planning.

One producer suggested relating how strategies in ecological weed management will affect insects and plant diseases. A general principle related to pest management is that crop diversity generally favors crops over pests. For example, diversifying crops in a rotation reduces the frequency a crop is grown; plant diseases proliferate if a crop is grown too frequently. In the Great Plains, sunflower, corn and winter wheat yield the most if grown only once every 4 years, reflecting lower disease incidence[10]. With winter wheat, Cook and Veseth[29] reported that delayed planting increases the susceptibility of wheat to root diseases. They suggested that producers will improve disease management more with other practices, such as diverse rotations and fertilizer placement, and encouraged producers not to delay planting for disease management.

Andow[32] found that plant insects, particularly those with limited host ranges, tended to be less abundant in diverse cropping systems. He suggested that crop diversity increases the populations of natural enemies of insect pests. With weeds, diversifying the rotation had the greater impact on population management (Fig. 1); similar results should occur with insects and plant diseases, as crop diversity is a key component of their management also.

A key to successful pest management from an ecological perspective is to integrate management tactics into the design of cropping systems[33]. Our goal with this planning tool is to help producers recognize crop choices and sequences that help weed management. With the multitude of crops now available in the Great Plains, producers can develop rotations that not only improve weed management, but also accrue additional agronomic and economic benefits with crop diversity in this semi-arid region[10].

References

1 Peterson, G.A., Schlegel, A.J., Tanaka, D.L., and Jones, O.R. 1996. Precipitation use efficiency as affected by cropping and tillage systems. Journal of Production Agriculture 9:180–186.

2 Bowman, R.A., Vigil, M.F., Nielsen, D.C., and Anderson, R.L. 1999. Soil organic matter changes in intensively cropped dryland systems. Soil Science Society of America Journal 63:186–191.

3 Anderson, R.L., Bowman, R.A, Nielsen, D.C., Vigil, M.F., Aiken, R.M., and Benjamin, J.G. 1999. Alternative crop rotations for the central Great Plains. Journal of Production Agriculture 12:95–99.

4 Zentner, R.P., Wall, D.D., Nagy, C.N., Smith, E.G., Young, D.L., Miller, P.R., Campbell, C.A., McConkey, B.G., Brandt, S.A., Lafond, G.P., Johnson, A.M., and Derksen, D.A. 2002. Economics of crop diversification and soil tillage opportunities in the Canadian prairies. Agronomy Journal 94:216–230.

5 Wright, A.T. 1990. Yield effect of pulses on subsequent cereal crops in the northern plains. Canadian Journal of Plant Science 70:1023–1032.

6 Peterson, G.A., Westfall, D.G., Toman, N.E., and Anderson, R.L. 1993. Sustainable dryland cropping systems: Economic analysis. Colorado State University Agricultural Experiment Station Technical Bulletin TB93–3.

7 Heap, I. 2003. The International Survey of Herbicide Resistant Weeds. Available at http://www.weedscience.com (verified January 9, 2003).

8 Beckie, H.J., Thomas, A.G., Legere, A., Kelner, D.J., van Acker, R.C., and Meers, S. 1999. Nature, occurrence, and cost of herbicide-resistant wild oat (*Avena fatua*) in small-grain production area. Weed Technology 113:612–625.

9 Mortensen, D.A., Bastiaans, L., and Sattin, M. 2000. The role of ecology in the development of weed management systems: an outlook. Weed Research 40:49–62.

10 Anderson, R.L. 2003. An ecological approach to strengthen weed management in the semiarid Great Plains. Advances in Agronomy 80:33–62.

11 Anderson, R.L. 2000. A cultural systems approach eliminates the need for herbicides in semiarid proso millet. Weed Technology 14:602–607.

12 Retzinger, E.J., Jr and Mallory-Smith, C.A. 1997. Classification of herbicides by site of action for weed resistance management strategies. Weed Technology 11:384–393.

13 Streibig, J.C. 1979. Numerical methods illustrating the phytosociology of crops in relation to weed flora. Journal of Applied Ecology 16:577–587.

14 Thomas, A.G. and Frick, B.L. 1993. Influence of tillage systems on weed abundance in southwestern Ontario. Weed Technology 7:699–705.

15 Roberts, H.A. 1981. Seed banks in soils. Advances in Applied Biology 6:1–55.

16 Entz, M.H., Bullied, W.J., and Katepa-Mupondwa, F. 1995. Rotational benefits of forage crops in Canadian Prairie Cropping Systems. Journal of Production Agriculture 8:521–529.

17 Lafond, G.P., Boyetchko, S.M., Brandt, S.A., Clayton, G.W., and Entz, M.H. 1996. Influence of changing tillage practices on crop production. Canadian Journal of Plant Science 76:641–649.

18 Ominski, P.D., Entz, M.H., and Kenkel, N. 1999. Weed suppression by *Medicago sativa* in subsequent cereal crops: a comparative survey. Weed Science 47:282–290.

19 Froud-Williams, R.J. 1988. Changes in weed flora with different tillage and agronomic management systems. In M.A. Altieri and M. Liebman (eds). Weed Management in Agroecosystems: Ecological Approaches. CRC Press, Boca Raton, FL. p. 213–236.

20 Anderson, R.L. 1994. Characterizing weed community seedling emergence for a semiarid site in Colorado. Weed Technology 8:245–249.

21 Mortimer, A.M. 1984. Population ecology and weed science. In R. Dirzo and J. Sarukhan (eds). Perspective on Plant Population Ecology. Sinauer Associates, Sunderland, MS. p. 363–388.

22 Anderson, R.L. 1999. Cultural strategies reduce weed densities in summer annual crops. Weed Technology 13:314–319.

23 Anderson, R.L. 2000. Cultural systems to aid weed manage-

ment in semiarid corn (*Zea mays*). Weed Technology 14:630–634.
24 Challaiah, Burnside, O.C., Wicks, G.A., and Johnson, V.A. 1986. Competition between winter wheat (*Triticum aestivum*) cultivars and downy brome (*Bromus tectorum*). Weed Science 34:689–693.
25 Anderson, R.L. 1997. Cultural systems can reduce reproductive potential of winter annual grasses. Weed Technology 11:608–613.
26 Seefeldt, S.S., Ogg, A.J., Jr, and Hou, Y. 1999. Near-isogenic lines for *Triticum aestivum* height and crop competitiveness. Weed Science 47:316–320.
27 Ogg, A.G., Jr and Seefeldt, S.S. 1999. Characterizing traits that enhance the competitiveness of winter wheat (*Triticum aestivum*) against jointed goatgrass (*Aegilops cylindrica*). Weed Science 47:74–80.
28 Anderson, R.L. 1996. Downy brome (*Bromus tectorum*) emergence variability in a semiarid region. Weed Technology 10:750–753.
29 Cook, R.J. and Veseth, R.J. 1991. Wheat Health Management. American Phytopathological Society Press, St. Paul MN.
30 Anderson, R.L. 1994. Planting date effect on no-till proso millet. Journal of Production Agriculture 7:454–458.
31 Anderson R.L. 2000. Ecology and interference of proso millet in semiarid corn. Weed Technology 14:45–50.
32 Andow, D.A. 1991. Vegetational diversity and arthropod population response. Annual Review of Entomology 36:561–586.
33 Holtzer, T.O., Anderson, R.L., McMullen, M.P., and Peairs, F.B. 1996. Integrated pest management for insects, plant pathogens, and weeds in dryland cropping systems of the Great Plains. Journal of Production Agriculture 9:200–208.